AD-A036 610 OFFICE OF THE OCEANOGRAPHER OF THE NAVY ALEXANDRIA VA F/G 15/1
A SPECIAL REPORT ON OCEANOGRAPHIC PROGRAM PLANNING FOR THE DEPU--ETC(U)
JUL 64

UNCLASSIFIED NL

1 OF 1
AD
A036610

ADA036610

MOST Project - 2

1

A SPECIAL REPORT ON OCEANOGRAPHIC PROGRAMS [illegible] FOR THE DEPUTY CHIEF OF NAVAL OPERATIONS

DDC
RECEIVED
MAR 7 1977
D

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

"In formulating policy it does help to ask the right questions instead of the wrong ones. If the alternatives are arrayed, and a serious attempt made to apply sound criteria in choosing the most efficient ones, decisions are likely to be improved . . ."

C. J. Hitch and R. N. McKean
The Economics of Defense in
the Nuclear Age, 1960

PREFACE

No matter what else the ten year program in oceanography does for the Navy, it must support the development and operational use of naval warfare systems. Yet, recently it has not done this, since system requirements have not become evident until late in the development process. It is perfectly obvious now, however, that oceanography must be harmonized with system development to improve the efficiency of decisions in both programs.

Management of the Navy's oceanographic program is much like management of the ASW program: it is made difficult by the fact that it is not one, but many, programs spread throughout the research and development and operational areas of the Navy. Yet in this diversity there would be strength, if it were possible to find a logical framework for oceanographic program planning which would ensure the timely solution of system development and operational problems. Although the oceanographic program cuts across both Office and Bureau lines, it should be adaptable to integrated program planning if the essential step of delineating oceanographic requirements is accomplished--either beforehand or as an integral part of the total program planning effort.

The present report on oceanographic program planning is concerned with the problem of oceanographic requirements for ASW systems and operations. It presents a new approach to looking at oceanographic requirements by considering the ASW systems, the operational decision criteria applicable to these systems, and the oceanographic data requirements pertinent to the operational decision criteria.

670113-0507

670113-0507

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

640731-0597

CONTENTS

FIGURES

TABLES

670113-0507

Page

White Section
Buff Section
Per Ltr. on file
AVAILABILITY CODES
and/or SPECIAL
A

D D C
RECEIVED
MAR 7 1977
D

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

I - BACKGROUND

The background for this study on critical characteristics of the ocean environment in antisubmarine warfare can be traced to 1950, when an operational requirement for oceanographic information (reference 1) was first issued. This requirement, which remains in effect today, specifies a need for the development of "new and improved techniques and equipment for the determination, interpretation, and application of oceanographic information". The features of this requirement are a "comprehensive program of research and development related to environmental conditions, physical oceanography, marine geology, boundary problems, biological oceanography, and propagation studies".

Despite its value at the time in keeping a small program intact and allowing for modest growth, this requirement did not distinguish between basic research, applied research, and surveys. By 1955, there were signs that the oceanographic program as a whole had not responded to system development requirements. The following statement, for example, appears in the Project NOBSKA report (reference 2) published early in 1956:

> "The most urgently needed supporting research and development in the field of active sonar include: oceanographic studies to identify clearly the regions where convergence zone, sound channels, and good reflecting bottoms are available."

Object!

shows that new things determined from WHOI etc should be pushed

The Project WHITE OAK report of 1959 (reference 3), relating to the protection of merchant shipping in the North Atlantic, was addressed less to oceanography than to antisubmarine warfare; however, the following comment from that report is also relevant:

> "The AN/SQS-26 system has been designed to overcome the bottom path propagation loss, not only for the average situation, but also for enough of the high loss situations to ensure that the system can operate in at least 85 percent of the deep water ocean areas."

It is now known that this statement is grossly in error. At the time it was written, concern was mounting over the backward state of oceanographic programs and the lack of systematic studies defining factors in oceanography critical to the development and employment of new antisubmarine warfare systems.

The Navy's first 10-year plan for oceanography was prepared in 1959 by the Office of Naval Research. A Panel on the Environment and Undersea Warfare was convened during the same year by the Committee on Undersea Warfare of the National Academy of Sciences-National Research Council. This Panel, meeting under the chairmanship of Dr. D. F. Leipper during 1959-60 and Dr. R. A. Frosch during 1960-61, undertook a study to determine the environmental information needed by the Navy in several different situations: design, testing, and strategic, operational, and tactical

planning (reference 4). When it became clear in the latter stages of the study that meaningful results would be impossible without considering the characteristics of individual systems, the study was abandoned. No report was issued by the National Academy of Sciences. (?)

Rear Admiral E. B. Hooper, Director of the Institute for Naval Studies in 1961, emphasized the value of presenting oceanographic data to the operating forces in a form which would facilitate operational decisions and suggest better means to exploit the seas (reference 5). Also in 1961 the first revision of TENOC was issued; the revised plan loosely related the objectives of various oceanographic studies to naval operational requirements. Commenting on the adequacy of TENOC-61 in support of antisubmarine warfare goals, the Chief of Naval Operations ASW Study Group reported (reference 6) as follows: Oceano? [illegible]?

> "While TENOC provides a cohesiveness to the Navy's oceanographic program, it includes, without priority guidance, oceanographic research of lesser importance to ASW and does not emphasize areas of greatest strategic interest. There are a prodigious number of oceanographic parameters which affect sonar performance, and therefore its proper design and optimum tactical use, but these can be arranged in order of significance from overriding to marginal. Similarly, all ocean areas of the world can conceivably be of strategic interest to ASW at some time, but these also can be designated in priority order."

About this time, Dr. R. O. Burns, Director of the Technical Analysis and Advisory Group of the Deputy Chief of Naval Operations for Development, described the mutually dependent roles of management and science in a paper published in the Navy Technical Forum (reference 7). In this paper the main theme was the application of operations research techniques to the management of science. But the greatest interest in this paper centered on discussion of a hypothetical problem related to the definition of critical oceanographic requirements for antisubmarine warfare. This new viewpoint on requirements and the initiative shown by the Director of the Antisubmarine Warfare Division (OP-32) and his staff to update the operational requirement for knowledge in oceanography (reference 8), set the stage for discussions between Dr. Burns and the Oceanographer of the Navy concerning a systematic study which would identify characteristics of the sea critical to antisubmarine warfare. Thereafter, the Deputy Chief of Naval Operations for Development requested (reference 9) that the Oceanographer undertake a study which would accomplish this purpose. The letter requesting the study stated the rationale for it as follows:

> "It has been generally conceded that our knowledge of the oceans is very limited. For this reason, a major oceanographic research program, TENOC, has been initiated. The plan for this, in general, is based on the assumption

that any and all increases in knowledge of the oceans will be beneficial to the Navy, and that no specific area of inquiry is more important than any other. For the most part detailed planning is dependent upon the interest of the participating scientists and opportunity for observations pertinent to those interests. It is recognized fully that most of the outstanding and startling discoveries have been the product of such undirected research, and that Navy sponsorship is both proper and essential.

?

"Nevertheless, the Navy, must, insofar as possible, insure that sponsored research will produce knowledge before it is needed for the solution of operating problems. It is for this reason that undirected research programs must be accompanied and augmented by programs of directed research. It is necessary, therefore, that operating problems of the future be anticipated with a reasonable degree of specificity. Only by so doing can a 'vector direction' be established as a guide for planning programs of directed research. Moreover, whenever possible, specific goals should be established in order to ensure that know-how will exist before it is needed to support advanced operating concepts and naval warfare systems."

ok.

redundant -

It was intended that tables of "critical characteristics of the ocean environment" should show clearly the goals and objectives of a program in applied oceanography and, at the same time, substantially contribute to the resolution of certain issues in oceanography raised by the Deputy Chief of Naval Operations for Fleet Operations and Readiness (reference 10). To the extent possible, these objectives have been met in this study.

II-IDENTIFICATION OF CRITICAL CHARACTERISTICS OF THE OCEAN ENVIRONMENT

Most of the general studies on antisubmarine warfare begin with first principles by evaluating the threat posed by an expanding Soviet submarine fleet, possible courses of Soviet action, alternative courses of counteraction, and so on. Since the results of recent investigations of these aspects of the antisubmarine warfare problem are available (reference 11), these steps have not been repeated.

This study commenced directly with a search of recent ASW literature, which yielded a list of 55 references and 171 different ways in which the environment affects ASW systems, tactics, and platforms. The environmental factors are listed in appendix A. When lists of the individual factors were compiled, it was recognized that they contained a wealth of information, but it was not evident that they could be translated directly into a list of ocean characteristics critical in antisubmarine warfare.

Thus a different approach which can be rationalized in the following way, was taken: naval officers and others are not generally concerned about the oceans for the sake of knowledge alone--they will become interested, however, if such knowledge helps or hinders performance of their assignments at sea. The wind and current

charts prepared by Lieutenant M. F. Maury for mariners over 100 years ago serve as a perfect example. The sailing master's attention was attracted not by the meanders of the Gulf Stream, but rather by the fact that these charts were the key to the fastest passage to Liverpool or Rio. Today, Navy tactics are predicated on the capabilities of modern warfare systems, which provide a link between the naval officer and oceanography.

Oceanography is associated closely with antisubmarine warfare, solely because the performance of ASW systems is controlled by the ocean environment to a greater degree than are other systems employed in naval warfare. This study, then, must investigate oceanographic requirements from the viewpoint of ASW systems. The first step was to compile a representative list of systems either in Fleet use or at some stage in the research and development process. This list, presented as table I, contains a brief description of 84 systems and is structured to distinguish between systems of nine different classes.

If the premise that knowledge of the seas is essential to optimize the effectiveness of naval warfare systems is correct, then it becomes necessary to determine to what degree oceanography enters into decisions concerning the design, development, installation, evaluation, and use of these systems. The objective, of

course, is to optimize decisions in which oceanography is a relevant factor--decisions such as: whether to approve the development of a new sonar or ASW missile system; where to install an underseas surveillance system; when to employ one mode of sound propagation rather than another; whether to fire an antisubmarine missile and so on. This is not meant to imply that oceanography is the only relevant factor in these decisions; it is obviously not. However, it is the critical factor in an increasing number of instances.

Recognition of the relevance of oceanography in ASW decisions thus suggested the possibility of categorizing the various criteria for decisions which have been found to be vital in antisubmarine warfare system planning and operations. A representative list of ASW operational decision criteria, which are the bases for making decisions, is given in table II.

Table II groups the operational decision criteria into four classes, each roughly describing the purpose of the decision involved: namely, system design, system operation, system performance, and system tactical employment. While decision criteria form the bases for decisions, they may become decisions when acted upon. For example, when the design for a system is optimized before approval is given for development, and the system

is subsequently developed to conform to these optimum specifications.

The D100 series of decision criteria relates to design and development of new systems. The D200 series illustrates decision criteria important to system operators who make dial settings on panels and equipment. Requirements for displaying these decision criteria can be specified only in general terms, until characteristics of a system and its displays are quite firmly established. This has already led to some difficulty.[1]

The D300 and D400 series indicate decision criteria important at various command levels from ASW Officer to Force Commander. Requirements for the real-time or other display of these decision criteria should be included in future new system requirement documents prepared by the Office of the Chief of Naval Operations.

The list of decision criteria in table II is intended to be representative and reasonably complete with respect to recurring decisions in which oceanography is related to antisubmarine warfare. The purpose in listing these decision criteria, however,

---

[1] The sonar data correction computer, AN/BQA-4(XN-1), between the AN/BQQ-2 sonar and the SUBROC fire control system requires a manual input of "down-slope bearing" and "bottom slope" when the sonar is operated in the bottom bounce mode. The distribution of slopes of Fresnel zone-sized areas

was to illustrate a new approach to formulating oceanographic data requirements; it was not to assume the prerogatives of system designers, planners, operators, and others in ASW who can specify more completely the relevant decision criteria in each phase of design, planning, and operations. Table II will serve well as a straw man.

Having available the characteristics of the systems listed in table I, the next objective was definition of the requirements for oceanographic data (table III) which if accomplished, would permit display of the decision criteria listed in table II. Lack of adequate empirical models and direct experimental evidence made this objective particularly difficult. In a rather complex sonar-fire control-missile system, for example, one should be able to specify the accuracy required for critical oceanographic data in all operational areas to ensure that a missile will fall with the designed circular error probable. Yet this could not be accomplished, owing to insufficient information on sound propagation errors.

Nonetheless, the characteristics of the systems of table I and the decision criteria of table II were the starting point in

---

[1] of the sea floor has not been determined. This is a case of oceanographic data being required for system employment, yet unavailable for that purpose, owing to inadequate coordination of the oceanographic and system development programs.

determining the requirements for oceanographic data in table III. The process was guided by available conversion models, experimental evidence of system performance, and the approximate state-of-the-art in the measurement of oceanographic data. In completing table III, which will also serve well as a straw man, it became clearly evident that:

a. The Navy's exploratory development program in oceanography has not produced the models needed for translating requirements for operational decision criteria into requirements for oceanographic data. Therefore dependable system analyses cannot be performed.

b. Accurate system analyses must be performed before development commences. These must establish the oceanographic data requirements for the system and the accuracy and form required for compatability with all decision criteria displays.

To determine which of the oceanographic data requirements listed in table III is first in importance, second, and so on, considering the systems and decision criteria discussed previously, a sensitivity analysis was performed along the following lines: a matrix (figure 1) was formed in which the column headings, R_i, represent the oceanographic data requirements given in table III; and the row headings, D_j, represent the decision criteria shown in table II. Each matrix element, m_{ij}, is an importance index which represents a value judgment of the relative importance of R_i in D_j on an arbitrary scale from zero to ten. Any matrix

		OCEANOGRAPHIC DATA REQUIREMENTS						
		R_1	R_2	R_3	. . .	. . .	R_i	. . .
OPERATIONAL DECISION CRITERIA	D_1	m_{11}	m_{21}	m_{31}	. . .	. . .	m_{i1}	. . .
	D_2	m_{12}	m_{22}	m_{32}	. . .	. . .	m_{i2}	. . .
	D_3	m_{13}	m_{23}	m_{33}	. . .	. . .	m_{i3}	. . .
	.	.	.	.			.	
	.	.	.	.			.	
	D_j	m_{1j}	m_{2j}	m_{3j}	. . .	. . .	m_{ij}	. . .
$\sum_i m_{ij}$		W_1	W_2	W_3	. . .	. . .	W_i	. . .

Figure 1: RELATIVE IMPORTANCE OF DATA REQUIREMENTS IN DECISION CRITERIA

m_{ij} = relative importance of R_i in D_j.

$W_i = \sum_i m_{ij}$ = weighting factor for R_i.

element, m_{ij}, different from zero shows that R_i is applicable in D_j with the indicated numerical value of relative importance, and that R_i is an "entry". A matrix element, m_{ij}, with a value of zero shows that R_i is of no importance in D_j and that R_i is not an "entry". Note that at least one maximum value of m_{ij} equal to 10 is associated with each D_j, and, in some instances, two or more maximum values of m_{ij} occur for D_j. That is, several different data requirements are judged to be highly important in a decision criteria. Summing the importance indices, m_{ij}, for a given column over all rows gives a total relative importance index, W_i, or a "weighting factor" for each R_i, considering all decision criteria.

Tables IV through VI are matrices of the form shown in figure 1, and each contains appropriate numerical values of m_{ij} and W_i. Note that the values of W_i appear as "totals" in the bottom rows of only tables IV, V and VI continued. For example, R101 appears in both table IV and table IV continued but the total relative importance index, W_i, equal to 386 appears only in table IV continued.

Results of this sensitivity analysis are summarized in table VII, in which the first three columns are data requirements, number of entries (R_i for which m_{ij} are different from zero), and weighting factors. The entries in the importance column are the

product of the number of entries, R_i, the weighting factors, W_i, and a scaling factor, 0.01. The importance column entries pertaining to Arctic data requirements R-107 through R-111 were further reduced by an additional scaling factor of 0.1 in order to place the importance of these requirements in perspective with the relatively small fraction of ocean within the Arctic Circle. In the final column of table VII, data requirements are ranked in importance from the lowest rank of 1 through the highest rank of 48.

The final ranking of oceanographic data requirements, based upon this sensitivity analysis, can be employed to investigate not only the balance of the total oceanographic program but also the trend of interest in oceanographic data over the last 5 to 10 years. It is easily seen that greater emphasis is now placed on statistical models of both ocean boundaries, the surface and the sea floor; on sound velocity data as a more direct index of underwater sound behavior; on the microstructure of properties of the sea; and on the nature and properties of the sub-bottom. A comparison between this ranking of data requirements and an independent ranking of classes of oceanographic information is made in section III.

III-RELATIONSHIP OF STUDY TO TENOC-64 OBJECTIVES

Relating the foregoing analyses to TENOC goals requires an understanding of the evolution of the Navy's program in oceanography since 1959. In that year, the Navy's first 10-year plan for oceanography was promulgated because of increased concern for an "oceanographic gap". This plan was forward-looking and was itself a milestone; however, it provided for growth only in the basic research program in oceanography, and its objectives were not clearly defined.

The first revision of the plan, TENOC-61, included all Navy programs; however, it also failed to set forth sound objectives based on naval requirements, as was noted in the CNO ASW Study Group report (reference 6).

The second revision of the TENOC plan, to be promulgated in April 1964, attempts to relate the importance of various subdivisions of oceanography to the several types of naval operations and development; to rank these subdivisions in order of priority to achieve balance throughout the program; and to specify objectives of research, development, and survey programs in oceanography.

Since the information prepared for TENOC-64 is most relevant to the questions posed by the Deputy Chief of Naval Operations

for Development, it is summarized briefly in this section. Table VIII shows a matrix of subdivisions of oceanography and related functions versus categories of naval operations and development. Each number in this matrix reflects a value judgment of the importance of a class of oceanographic program to a particular operation - the higher the number, the greater the importance. In the case of amphibious operations, for example, the highest values are assigned to oceanographic forecasting and littoral (coastal) studies, indicating that the success or failure of such operations may well depend upon accurate wave and surf forecasts and upon nearshore depths and the nature of beaches. Conversely, low values indicate subdivisions and functions having only marginal or isolated influence.

Table IX summarizes the material in table VIII by ranking importance of the oceanographic subdivisions with the highest number representing greatest importance. Just as some variables rank higher than others, there are also disparities in the status of knowledge among the subdivisions which must be considered in determining program priorities. Obviously, if more is known about one oceanographic variable than another and the importance of both to naval operations and development is equal, then the least understood variable should be accorded the higher priority.

Hence, priority equals class importance divided by relative status of knowledge. The priorities for each class, determined with this method, are ranked with 18 being the highest. Underwater acoustics was found to be highest in priority, oceanographic forecasting second highest and so on. The last two columns of table IX show the required research, development, and survey programs for each class.

Carrying this approach one step farther, it is recognized that naval operations are more likely to occur in some areas than in others, and therefore applied oceanographic research and surveys in areas of probable operations should also be accorded high priority. After investigation of requirements for all classes of naval operations, the ocean has been subdivided into five areas according to priority, the highest value having highest priority (figure 2). The following example illustrates how class and area priorities can be used to determine the value of a particular program. An oceanographic cruise, planned off the eastern coast of the United States, would include acoustical sea floor, sound velocity, and current studies directly contributing to the required research, development, and survey programs cited previously. The resultant value of this effort is the

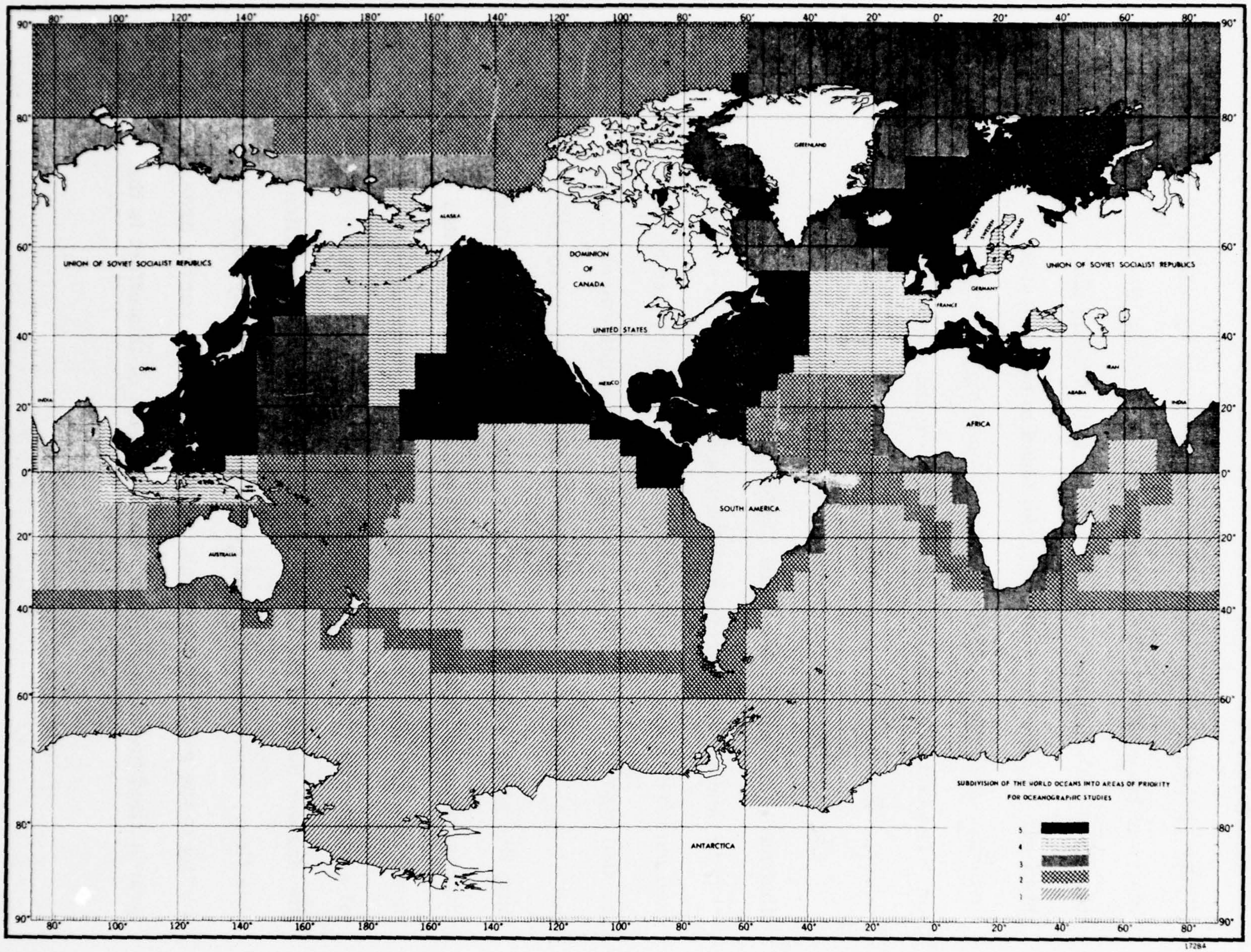
UNION OF SOVIET SOCIALIST REPUBLICS
GREENLAND
ALASKA
DOMINION OF CANADA
UNITED STATES
MEXICO
SOUTH AMERICA
GERMANY
FRANCE
AFRICA
ARABIA
IRAN
INDIA
CHINA
AUSTRALIA
ANTARCTICA
SUBDIVISION OF THE WORLD OCEANS INTO AREAS OF PRIORITY FOR OCEANOGRAPHIC STUDIES
5
4
3
2
1
17284

Figure 2

product of the sum of the several class priorities and the area priority, in this instance, 265.

In contrast, the value of a cruise planned solely for marine biological studies in the equatorial Atlantic would be only 16, or less by a factor of roughly 15, which implies that the sensitivity of such an analysis is adequate to appraise the relative value of oceanographic programs.

With oceanographic programs ranked in importance for TENOC and oceanographic data requirements ranked in priority for this study, table X shows remarkably good agreement between the two studies considering the analyses were performed independently.

The approach taken in this study to identify systems, decision criteria, and oceanographic requirements seems perfectly logical, but obviously the value judgments involved at each stage are not intended to substitute for quantitative system analyses. It can be concluded that while this study might behelpful in establishing a 'vector direction' for elements of a comprehensive program, it is less useful in defining objectives of these programs. Unqualified use of the results of this analysis in planning would involve a considerable degree of risk.

REFERENCES

1. CNO ltr ser 0264P34 of 10 August 1950; Subj: Navy Research and Development Plan; Operational Requirement No. IO-15401 (Oceanographic Information).

2. Committee on Undersea Warfare, National Academy of Sciences - National Research Council: Project NOBSKA; Final Report, Volume II, 1 March 1957, p 67.

3. Office of Naval Research: Project White Oak; CNR ser 1084 of 31 July 1959, p 117.

4. Report on the First Meeting of the Panel on the Environment and Undersea Warfare, 18-19 January 1960; NRC: CUW:0274. See also, Memorandum to Panel Members from Dr. R. A. Frosch dated 1 April 1960.

5. Director, INS ltr Op09E ser 98-61 of 28 June 1961; Subj: Oceanography Data.

6. Report of the Chief of Naval Operations ASW Study Group, 1962, Volume V, pp 56-57.

7. Burns, R. O., Management and Science, Navy Technical Forum, Spring, 1962, pp 35-50.

8. Informal discussions between the Director, Antisubmarine Warfare Division and the Oceanographer of the Navy.

9. CNO ltr ser 154P07T of 31 July 1962; Subj: Tables of "Critical Characteristics of Ocean Environment"; establishment of project on.

10. OPNAV Memorandum for the Oceanographer of the Navy ser 0367P32 of 13 December 1963; Subj: The Operators' Need for Knowledge in Oceanography.

11. Report of the Chief of Naval Operations ASW Study Group, Volumes I & II, 1962.

TABLE I

ANTISUBMARINE WARFARE SYSTEMS

S100 ACOUSTIC - DETECTION AND TRACKING SYSTEMS

S110 - SURFACE SHIP SONAR SYSTEMS

S111	AN/SQS-29, 30, 31 & 32	Active, medium-range sonar for surface ships.
S112	AN/SQS-17	Active, medium-range sonar for PC ships.
S113	AN/SQS-33 (Modified SQS-20)	Active-passive detection and tracking sonar for surface ships.
S114	AN/SQS-23	Active long-range, detection and tracking sonar.
S115	PADLOC	Integrated active-passive sonar for surface ships employing cross correlation signal processing.
S116 -	TOWED HYDROPHONE ARRAY SONAR SYSTEM	Active-passive detection and classification sonar system using a hydrophone array which can be towed at 2,000-foot depths and up to 1,000 feet astern.
S117	AN/SQS-26	Active-passive long-range, detection and tracking sonar.
S118	AN/SQQ-20	Integrated, active-passive sonar system for SEAHAWK. Capabilities include cryptographically secure communications, general purpose, acoustic communications, and IFF.

TABLE I (Con.)

ANTISUBMARINE WARFARE SYSTEMS

S119	ACTIVE PLANAR ARRAY SONAR	Long-range, active-passive sonar using conformal or planar array transducers.
S120	CONTACT	Improved bottom-bounce and convergence zone sonar for surface ships.
S130 -	SURFACE SHIP VARIABLE DEPTH SONAR SYSTEMS	
S131	AN/SQA-8	VDS system for use with AN/SQS 31 and 32 sonars.
S132	AN/SQS-9	VDS system for PC ships.
S133	AN/SQA-10	VDS system for use with AN/SQS-29 and 32 sonars.
S134	AN/SQA-13	Small ship VDS system for use with AN/SQS-17 sonar.
S135	AN/SQA-19 & 11	VDS system for use with AN/SQS-23 sonar.
S136	AN/SQS-35	VDS system for small ships.
S137	AN/SQA-17	Experimental VDS sonar for evaluation of bottom-bounce and convergence zone propagation.
S150 -	SUBMARINE SONAR SYSTEMS	
S151	AN/BQS-2	Short-range active sonar.
S152	AN/BQS-4	Medium-range active sonar.
S153	AN/BQR-3	Medium-range passive sonar.

TABLE I (Con.)

ANTISUBMARINE WARFARE SYSTEMS

S154	AN/BQR-2B	Long-range passive sonar.
S155	AN/BQR-4	Long-range passive sonar.
S156	AN/BQR-7	Long-range passive sonar.
S157	AN/BQS-8 (ARCTIC SONAR)	Integrated, active ice detecting and ranging sonar.
S158	VERSUS	Experimental vertical array sonar.
S159	AN/BQS-6	Active-passive, long-range sonar.
S160	AN/BQQ-2	Coordinated sonar system for new construction submarines which includes the following subsystems: (a) AN/BQG-1 (PUFFS), for passive ranging at low speed. (b) AN/BQR-7 (conformal array) for long-range passive detection, tracking, and classification at low speed. (c) AN/BQS-6 (spherical array, passive) for detection and tracking at high speed and fire control. (d) Spherical array, active: search in scanning or tribeam modes. (e) Spherical array, communications: includes secure long-range sonar communications (SESCO-AN/BQA-3) and short-range communications (Voice). (f) AN/BQQ-3 (LOFAR), for target classification by frequency analysis.

TABLE I (Con.)

ANTISUBMARINE WARFARE SYSTEMS

S161	AN/BQQ-1	Coordinated sonar system identical to AN/BQQ-2 without PUFFS and LOFAR.
S162	SISS	Sonar system similar to AN/BQQ-2.
S170 -	HELICOPTER SONAR SYSTEMS	
S171	AN/AQS-10	Active dipping sonar.
S172	AN/AQS-12	Active dipping sonar.
S173	HELO TOWED SONAR	Sonar capable of being towed during the final attack phase.
S174	FAST-DIP SONAR	Active, deep-dipping sonar.
S175	AIR TRANSPORTABLE SURVEILLANCE SONAR (ATSS)	*Air-transportable*, deep-dipping surveillance sonar.
S180 -	AIRCRAFT SONOBUOY DETECTION SYSTEMS	
S181	JEZEBEL	Passive detection system for fixed-wing aircraft.
S182	JULIE	Explosive echo-ranging system for fixed-wing aircraft.
S183	DEEP JULIE	Second-generation, explosive echo-ranging system for fixed-wing aircraft.
S184	JOINT CANADIAN/U. S. SURVEILLANCE SYSTEM (Project NUTMEG)	Moored sonobuoy surveillance system for aircraft monitoring.

TABLE I (Con.)

ANTISUBMARINE WARFARE SYSTEMS

	S185	AIRBORNE ACTIVE SONOBUOY SYSTEM	Active sonobuoy system for fixed-wing aircraft with capability for detecting, classifying, and tracking deep submerged and quiet-running submarines.
S200	ANTISUBMARINE MISSILE SYSTEMS		
	S201	ASROC	Surface ship-launched missile with nuclear depth charge or homing torpedo warhead. Nuclear depth charge: 3, 500 to 10, 000 yards. MK 44 torpedo: 1, 000 to 10, 000 yards.
	S202	EXTENDED RANGE ASROC MISSILE	Antisubmarine weapon system for surface ships. Range, 1, 500 to 18, 000 yards with nuclear depth charge or homing torpedo payload.
	S203	SUBROC	Submarine-launched, antisubmarine missile with nuclear capability and range to 70, 000 yards.
	S204	SS ASW ROCKET	Submarine-launched, ASW rocket with MK 46 torpedo payload, and range to 70, 000 yards.
S300	FIXED SURVEILLANCE SYSTEMS		
	S301	SOUND SURVEILLANCE SYSTEM (SOSUS)	Network of bottom-mounted, passive hydrophone arrays and shore stations for detecting submarines approaching the continental United States.

TABLE I (Con.)

ANTISUBMARINE WARFARE SYSTEMS

	S302	COLOSSUS I	Bottom-mounted, active barrier system for detecting submarines transiting shallow water (50 to 500 fathoms) straits and passages.
	S303	ARTEMIS	Experimental system designed to determine the feasibility of active, underwater surveillance to 500 miles.
	S304	FISHBOWL	Experimental, bottom-mounted scanning sonar.
	S305	RSR	Deep water, active system with a detection range of the order of 100 miles. Utilizes the refracted-surface-reflected (RSR) propagation path to the third zone.
S400	ASW TORPEDO SYSTEMS		
	S401	TORPEDO MK 37 MOD O	Submarine or surface ship-launched active or passive homing torpedo.
	S402	TORPEDO MK 37 MOD 1	Submarine or surface ship-launched, wire-guided, active or passive acoustic homing torpedo.
	S403	TORPEDO MK 44	Lightweight surface ship or aircraft-launched active or passive acoustic homing torpedo.
	S404	TORPEDO MK 45	Submarine-launched, wire or gyro-guided nuclear torpedo.

TABLE I (Con.)

ANTISUBMARINE WARFARE SYSTEMS

S405	TORPEDO MK 46	Lightweight, surface ship or aircraft-launched, high speed active or passive acoustic homing torpedo.
S406	TORPEDO EX-10	Submarine or surface ship-launched, wire-guided active or passive acoustic homing torpedo.
S407	ASTOR	Nuclear, wire-guided torpedo for submarines.

S500 ANTISUBMARINE MINING SYSTEMS

S510 - BOTTOM MINES

S511	AERIAL MINING WEAPON SYSTEM MK 52	An aircraft-laid, 1,000-lb bottom influence mine.
S512	AERIAL MINING WEAPON SYSTEM MK 55	Aircraft-laid, 2,000-lb. bottom influence mine.
S513	AERIAL MINING WEAPON SYSTEM MK 58	Aircraft-laid, 500-lb. bottom influence mine.
S514	SUBMARINE LAUNCHED MOBILE MINE	Mobile mine utilizing conventional torpedo propulsion system.

S520 - MOORED MINES

S521	SUBMARINE MINING WEAPON SYSTEM MK 57	Submarine-laid, 2,000-lb moored mine.
S522	CAPTOR	Homing mine which can be planted by aircraft, submarines, or surface ships. Capsule can be moored in depths of 1,000 to 1,500 ft.

TABLE I (Con.)

ANTISUBMARINE WARFARE SYSTEMS

S523	ANTI-INVASION MINE (SMALL AUXILIARY MINE)	Small, moored contact mine to be used offensively and covertly against small vessels (5 to 200 tons).

S600 NON-ACOUSTIC DETECTION AND CLASSIFICATION SYSTEMS

S610 MAGNETIC ANOMALY DETECTION SYSTEMS

S611	AN/ASQ-8-10	Magnetic anomaly detection system for fixed-wing aircraft.
S612	AN/ASQ-46	Towed, magnetic anomaly detection system for aircraft.
S613	AN/ASQ-60	Towed, magnetic anomaly detection system for rotary-wing aircraft.
S614	AN/ASQ-81	Towed, helium, magnetic anomaly detection system for aircraft.

S620 RADAR

S621	AIRBORNE ASW RADAR	High resolution periscope detection radar for fixed-wing aircraft.
S622	SHIPBOARD ASW RADAR	High resolution periscope detection radar for surface ships.

S630 INFRARED

S631	AN/AAR-29	Fixed-wing aircraft infrared detection system.

TABLE I (Con.)

ANTISUBMARINE WARFARE SYSTEMS

S632	AN/AAD-2	Fixed-wing aircraft line-scan infrared detection system.

S700 COMMAND AND CONTROL SYSTEMS

S710	COMMUNICATIONS	
S711	SUBMARINE SUBMERGED COMMUNICATION ANTENNA SYSTEMS	System for submarine to surface ship and aircraft communications, with VLF reception at keel depths of 250 ft. Major components include: buoy antenna systems AN/BRA-10 & 12, expendable communication buoys, fixed length and reelable floating wire antennae.
S712	SECURE SUBMARINE COMMUNICATIONS (SESCO)	Semi-secure system for underwater communication between submarines at ranges to 70 miles.
S713	SHORT PULSE MESSAGE EQUIPMENT (SPUME)	Underwater acoustic communication system for submarines which transmits short, high-power pulses.
S714	GENERAL PURPOSE VOICE COMMUNICATION SYSTEM (GPVC)	Non-secure communication system for submarines available as part of SESCO or SPUME.

TABLE I (Con.)

ANTISUBMARINE WARFARE SYSTEMS

S715	AN/WQC-2 (XN-1)	Omnidirectional, high-power, single side band, voice acoustic system for surface ship and submarine underwater communications and IFF.
S716	AN/UQC-1	Short range, acoustic, underwater communication system for destroyers and submarines.
S720	NAVIGATION SYSTEMS	
S721	AN/BQN-3	Sonar sounding system used with the inertial navigation subsystem in 598 through 616 class submarines.

S800 TEST AND EVALUATION SYSTEMS

S801	ATLANTIC UNDERSEA TEST AND EVALUATION CENTER (AUTEC)	All-Navy, deep-water test center instrumented to permit a wide variety of tests, measurements, investigations and evaluations to be made under actual deep sea conditions.
S812	INTERIM TORPEDO TRACKING RANGE	Operational evaluation range for torpedoes near St. Croix, V. I.

S900 ANTISUBMARINE WARFARE PLATFORMS

S901 AIRCRAFT: FIXED WING

S902 AIRCRAFT: ROTARY WING

TABLE I (Con.)

ANTISUBMARINE WARFARE SYSTEMS

S903 SURFACE SHIPS (INCLUDING HYDROFOILS)

S904 SUBMARINES

TABLE II

OPERATIONAL DECISION CRITERIA — 4 classes

D100	System Design	
	D101	Optimum detection system characteristics: frequency, pulse type, pulse length, keying rate, bandwidth, source level, receiving sensitivity, beamwidth, beam depression angle, etc.
	D102	Optimum signal processing techniques: filtering, sampling, etc.
	D103	Maximum operating depth for variable depth sonar.
	D104	Maximum operating depth for helicopter sonar.
	D105	Optimum locations for fixed surveillance and test and evaluation installations.
	D106	Optimum deep sea cable routes.
	D107	Optimum hydrophone depths: Julie, Jezebel, Nutmeg, etc.
	D108	Optimum life expectancy of submerged systems.
	D109	Optimum frequency, bandwidth and sensitivity for acoustic, magnetic, and pressure mine sensors.
	D110	Optimum torpedo search pattern.
D200	System Operation	
	D201	Surface channel sound velocity.
	D202	Optimum sonar operating mode.
	D203	Optimum beam depression angle: convergence zone, bottom bounce.

TABLE II (Con.)

OPERATIONAL DECISION CRITERIA

D204	Optimum sonar pulse length.
D205	Mean horizontal sound velocity: direct path, convergence zone, bottom bounce.
D206	Ocean depth.
D207	Bottom slope angle bearing.
D208	Bottom slope angle.
D209	Optimum sonobuoy pattern and spacing.
D210	Optimum system operational depth: variable depth sonar, helicopter dipping sonar, explosive source for Julie and underwater communications, hydrophones for Julie, Jezebel, Nutmeg, etc.
D211	Optimum mine spacing and depth.
D212	Acoustic, magnetic, and pressure mine threshold settings.
D213	Magnetic anomaly detection system filter settings.
D214	Optimum source level: sonar, echo sounder for bathymetric navigation.
D215	Navigational accuracy.
D216	Optimum torpedo speed and depth.

D300 System Performance

D301	Range and probability of active and passive sonar detection under given operating and environmental conditions, at various target aspects, depths, and speeds.

TABLE II (Con.)

OPERATIONAL DECISION CRITERIA

D302	Maximum range of underwater communications.
D303	Weapon hit probability.
D304	Sonar range and bearing errors.
D305	Bearing accuracy versus time: sound recorder, sonobuoys, etc.
D306	False alarm rate: acoustic, magnetic, infrared, radar, etc.
D307	Probability of torpedo capture: surface, sea floor, ice, marine life, etc.
D308	Probability of mine burial.
D309	Probable depth of mine burial on impact or afterwards.
D310	Decrease in minefield effectiveness resulting from mine burial and/or marine fouling.
D311	Decrease in minefield effectiveness resulting from mine dip.
D312	Probability of mine firing from false pressure, acoustic, and/or magnetic noise signals.
D313	Probability of electromagnetic (visual, infrared, radar) detection under given operating and environmental conditions at various target aspects, depths, and speeds.
D314	Decrease in system effectiveness resulting from ocean currents and/or sea ice.

TABLE II (Con.)

OPERATIONAL DECISION CRITERIA

D400 System Tactical Employment

- D401 Optimum sea routes: defensive, offensive, favorable weather, etc.
- D402 Optimum submarine listening depth.
- D403 Optimum submarine operating depth to avoid acoustical detection.
- D404 Minimum submarine depth for visual concealment.
- D405 Areas and times for variable depth sonar operations.
- D406 Areas and times for convergence-zone sonar operations.
- D407 Areas and times for bottom bounce sonar operations.
- D408 Areas and times for hull-mounted sonar operations (unaffected by surface waves).
- D409 Areas and times for hull-mounted sonar operations (unaffected by bottom reverberation).
- D410 Areas and times for reliable acoustic path propagation.
- D411 Areas and times for electromagnetic detection system operations.
- D412 Range of underwater detectability: surface forces; submarines.
- D413 Optimum deployment of forces, including screen and screen spacing.

TABLE II (Con.)

OPERATIONAL DECISION CRITERIA

D414	Limits of dangerous radioactive contamination.
D415	Optimum aircraft search altitude and azimuth: radar, infrared, MAD, visual sighting of submerged submarines, mines, etc.
D416	Safe standoff distance for firing nuclear weapons.
D417	Maximum keel depth for electromagnetic communications.

TABLE III

OCEANOGRAPHIC DATA REQUIREMENTS

R100	Surface	
	R101	Mean wave height: ± 1 ft or 10%, whichever is greater.
	R102	Surface elevation, slope, and curvature spectra: ± 10%.
	R103	Direction of primary surface waves: ± 30°
	R104	Second order statistics of sea surface: ± 20%.
	R105	Surface current: ± 0.1 knot.
	R106	Differential surface current for various separation distances: ± 0.1 knot.
	R107	Areal coverage and limit of sea ice: coverage ± 10%; limit ± 20 miles.
	R108	Thickness of sea ice: ± 1 ft or 10% whichever is greater.
	R109	Maximum depth of ice islands, pressure ridge projections and icebergs: ± 10%.
	R110	Sea ice depression and slope spectra: ± 10%.
	R111	Rigidity, density, sound velocity and sound absorption of sea ice: ± 10%.
	R112	Water temperature: ± 0.1°F.
	R113	Air-sea temperature difference: ± 0.2°F.
	R114	Salinity: ± $0.02^{\circ}/oo$.
	R115	Frequency of fog and precipitation: ± 10%.

TABLE III (Con.)

OCEANOGRAPHIC DATA REQUIREMENTS

R200 Volume

R201	Sound velocity, continuous profile to bottom: ± 1 ft/sec.
R202	RMS horizontal sound velocity fluctuation and correlation distance vs depth: ± 1 ft/sec, ± 10%.
R203	Mean horizontal sound velocity gradient vs depth: ± 1 ft/sec/ft.
R204	Ocean current, speed and direction profile to bottom: ± 0.1 knot, ± 30°.
R205	Probability of occurrence, depth, and scattering strength of biological scattering layer(s): ± 10%.
R206	Dissolved oxygen concentration: ± 0.1 ml/l.
R207	Probability of presence and concentration of entrapped or undissolved gas: ± 10%.
R208	False target density: ± 10%.
R209	Spectral intensity and directional distribution of ambient noise: ± 2 db, ± 20°.
R210	Internal wave elevation spectrum vs depth: ± 10%.
R211	Light extinction coefficients: ± 1%.
R212	Spectral intensity and directional distribution of electromagnetic noise: ± 10%.
R213	Geomagnetic field strength, field strength gradients and fluctuations: ± 0.1 gamma; ± 0.1 gamma/mile.

TABLE III (Con.)

OCEANOGRAPHIC DATA REQUIREMENTS

R214 Tidal range and level: ± 1 ft.

R215 Probability of bioluminescence: ± 10%.

R216 Rate of accretion of marine growth on various surfaces: ± 1 mm/dm^2/month.

R217 Sound absorption: ± 5%.

R218 Boundary scattering, reflectivity, and absorption: ± 10%.

R300 Bottom

R301 Ocean depth: ± 1 fathom.

R302 Bottom elevation and slope spectra: ± 1 fathom; ± 1°.

32 R303 Surface sediment density, porosity, sound velocity: ± 1°.

30 R304 Thickness of sedimentary layer: ± 10%.

28 R305 Density, sound velocity, and rigidity of intrasediment layers: ± 10%.

17 R306 Depth of boundaries and thickness of intrasediment layers: ± 10%.

10 R307 Surface sediment grain size and shear strength: ± 10%.

R308 Ratio of sediment to exposed pebbles, rock, or nodules on sea floor: ± 0.1.

R309 Depth, thickness, and boundary roughness of subsediment layers: ± 10%.

TABLE III (Con.)

OCEANOGRAPHIC DATA REQUIREMENTS

R310	Density, sound velocity, and rigidity of subsediment layers: $\pm 10\%$.
R311	Bottom pressure spectra: $\pm$ 0.1 inch of water.
R312	Probability of turbidity currents: $\pm 10\%$.
R313	Water temperature: $\pm 0.1^{o}F$.
R314	Color of bottom sediments.
R315	Gravimetric profiles.

RELATIVE IMPORTANCE OF DATA REQUIREMENTS (R_i) IN DECISION CRITERIA (D_j)

	R 101	R 102	R 103	R 104	R 105	R 106	R 107	R 108	R 109	R 110	R 111	R 112	R 113	R 114	R 115
D101	8	6	0	4	0	0	8	4	4	3	6	8	10	2	0
D102	8	6	0	4	0	0	8	4	1	2	6	8	0	1	0
D103	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D104	4	4	0	0	2	0	0	0	0	0	0	0	0	0	0
D105	8	6	6	4	8	6	8	6	8	2	4	9	0	2	0
D106	6	6	0	0	0	0	0	0	0	0	0	0	0	0	0
D107	8	6	0	4	4	4	0	0	0	0	0	8	0	2	0
D108	0	0	0	0	0	0	0	0	6	0	0	9	0	10	0
D109	9	3	0	0	0	0	0	0	0	0	0	8	0	2	0
D110	10	8	0	6	8	0	9	8	8	4	2	8	0	0	0
Sub-total	61	45	6	22	22	10	33	22	27	11	18	58	10	19	0
D201	10	8	6	5	2	0	9	9	4	4	8	10	0	2	0
D202	10	8	6	5	2	0	10	9	4	0	8	10	0	2	0
D203	9	8	6	6	0	0	9	8	8	6	8	0	0	0	0
D204	8	7	5	5	0	0	9	5	4	4	8	0	0	0	0
D205	10	7	4	5	0	0	10	8	4	4	6	10	0	2	0
D206	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D207	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D208	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D209	9	9	8	5	9	9	10	5	5	3	4	4	0	0	0
D210	10	8	6	5	4	0	8	5	5	3	3	4	0	0	0
D211	7	4	4	4	6	4	8	5	0	0	0	0	0	0	0
D212	10	0	5	0	0	0	8	6	4	0	0	0	0	0	0
D213	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D214	9	0	5	4	0	0	8	6	4	0	4	4	0	2	0
D215	6	0	6	0	8	0	0	0	0	0	0	0	0	0	8
D216	8	7	7	0	9	0	9	8	8	5	6	0	0	0	0
Sub-total	106	66	68	44	40	13	98	74	50	29	55	42	0	8	8

TABLE IV

RELATIVE IMPORTANCE OF DATA REQUIREMENTS (R_i) IN DECISION CRITERIA (D_j)

	R 101	R 102	R 103	R 104	R 105	R 106	R 107	R 108	R 109	R 110	R 111	R 112	R 113	R 114	R 115
D301	10	6	6	4	4	0	9	5	4	3	6	8	0	2	0
D302	5	4	5	4	0	0	5	4	4	0	5	8	0	2	0
D303	9	6	6	4	8	2	8	6	4	3	5	7	0	2	0
D304	5	4	4	3	0	0	5	4	3	3	4	2	0	1	0
D305	6	4	4	3	2	2	5	0	0	0	0	0	0	0	0
D306	10	7	6	4	4	0	7	6	4	0	0	4	4	0	6
D307	10	7	6	3	5	3	8	8	8	3	3	4	0	0	0
D308	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D309	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D310	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D311	6	0	6	0	8	0	0	0	0	0	0	0	0	0	0
D312	9	0	0	0	0	0	6	5	4	0	0	0	0	0	0
D313	10	8	6	4	5	0	8	4	0	0	0	9	10	0	10
D314	0	0	0	0	10	8	10	8	8	8	9	0	0	0	0
Sub-total	80	46	49	29	46	15	71	50	39	20	32	42	14	7	16
D401	10	7	8	6	8	4	9	6	6	2	2	9	8	2	8
D402	9	7	4	0	0	0	4	4	4	0	4	4	0	2	0
D403	7	4	4	0	0	0	6	4	0	0	5	0	0	0	0
D404	8	0	6	0	0	0	10	0	0	0	0	0	0	0	10
D405	10	6	4	6	0	0	5	5	0	0	0	0	0	0	0
D406	10	8	4	6	0	0	9	7	7	4	5	0	0	0	0
D407	10	8	4	6	0	0	9	7	7	4	5	0	0	0	0
D408	10	8	4	4	0	0	9	7	4	4	0	0	0	0	0
D409	5	3	4	4	0	0	9	7	0	0	0	0	0	0	0
D410	6	4	3	3	0	0	0	0	0	0	0	0	0	0	0
D411	8	6	5	3	0	0	10	0	0	0	0	0	0	0	0
D412	10	8	0	0	0	0	10	7	7	6	7	0	0	0	0
D413	10	8	0	0	6	4	8	7	7	4	0	4	4	2	0
D414	6	0	6	0	10	8	0	0	0	0	0	0	0	0	0
D415	10	8	6	4	0	0	10	0	0	0	0	10	8	0	10
D416	0	0	8	0	10	0	0	0	0	0	0	0	0	0	0
D417	10	0	0	0	0	0	8	0	0	0	0	0	0	0	0
Sub-total	139	85	70	42	34	16	116	61	42	24	28	27	20	6	28
Total	386	242	193	137	142	54	318	207	158	84	133	169	44	40	52

TABLE IV (con.)

RELATIVE IMPORTANCE OF DATA REQUIREMENTS (R_i) IN DECISION CRITERIA (D_j)

	R 201	R 202	R 203	R 204	R 205	R 206	R 207	R 208	R 209	R 210	R 211	R 212	R 213	R 214	R 215	R 216	R 217	R 218
D101	10	6	8	1	5	0	1	6	8	0	0	0	0	0	0	5	10	10
D102	10	6	8	1	5	0	1	6	9	0	0	0	0	0	0	5	10	10
D103	10	4	4	5	5	0	1	4	3	0	0	0	0	0	0	0	5	2
D104	10	4	4	5	5	0	1	4	3	0	0	0	0	0	0	0	5	2
D105	10	6	8	9	8	0	2	8	9	2	0	0	0	8	0	9	4	2
D106	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
D107	10	8	8	8	9	0	1	8	9	2	0	0	0	0	0	1	5	2
D108	0	0	0	10	0	6	0	0	0	0	0	0	0	8	0	10	0	0
D109	8	3	3	3	0	0	1	8	10	0	0	1	6	5	0	7	7	3
D110	10	10	10	8	6	0	0	8	9	2	0	0	0	0	0	0	2	4
Sub-total	84	47	53	50	43	6	8	52	60	6	0	1	6	21	0	42	48	35
D201	10	10	10	0	0	0	2	0	0	0	0	0	0	0	0	0	4	8
D202	10	9	9	0	6	0	0	8	9	4	0	0	0	0	0	0	5	4
D203	10	8	8	0	0	0	0	4	4	4	0	0	0	0	0	0	4	6
D204	10	8	8	0	5	0	2	5	6	0	0	0	0	0	0	0	8	8
D205	10	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	4	8
D206	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
D207	5	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D208	5	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D209	10	9	9	10	8	0	2	8	9	4	0	0	0	0	0	0	9	4
D210	10	9	9	3	8	0	0	4	8	4	0	0	0	0	0	0	5	2
D211	10	8	6	9	4	0	0	8	10	0	6	5	6	10	0	10	9	6
D212	9	8	8	0	0	0	0	8	9	0	0	5	6	8	0	10	10	4
D213	0	0	0	0	0	0	0	0	0	0	0	5	10	0	0	0	0	0
D214	9	9	8	0	8	0	0	0	9	4	0	0	0	0	0	0	10	10
D215	9	9	8	0	8	0	0	0	9	4	0	0	0	0	0	0	2	2
D216	9	9	9	9	6	0	0	0	9	0	0	0	0	0	0	0	2	7
Sub-total	126	116	112	31	53	0	6	45	82	24	6	15	22	18	0	20	74	71

TABLE V

RELATIVE IMPORTANCE OF DATA REQUIREMENTS (R_i) IN DECISION CRITERIA (D_j)

	R 201	R 202	R 203	R 204	R 205	R 206	R 207	R 208	R 209	R 210	R 211	R 212	R 213	R 214	R 215	R 216	R 217	R 218
D301	10	10	10	4	8	0	3	7	8	2	0	0	0	0	0	0	8	8
D302	10	10	10	0	8	0	0	0	8	2	0	0	0	0	0	0	10	3
D303	10	10	10	8	7	0	2	8	8	1	0	0	0	0	0	0	6	6
D304	10	10	10	0	8	0	0	0	7	1	0	0	0	0	0	0	7	0
D305	10	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3
D306	0	0	0	0	4	0	0	9	9	3	0	6	2	0	0	0	3	3
D307	8	7	7	5	10	0	0	7	9	0	0	0	0	0	0	0	3	5
D308	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D309	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D310	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	10	0	0
D311	0	0	0	10	0	0	0	0	0	0	0	0	0	9	0	8	0	0
D312	8	8	8	0	0	0	0	9	10	0	0	5	8	0	0	0	6	3
D313	0	0	0	0	0	0	0	10	0	0	9	9	0	0	4	0	0	0
D314	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sub-total	66	65	65	48	45	0	5	50	59	9	9	20	10	9	4	18	45	31
D401	10	10	10	4	8	0	0	9	9	2	5	6	4	4	2	0	6	6
D402	10	10	10	4	8	0	0	10	10	2	0	0	0	0	0	0	7	4
D403	10	10	10	0	9	0	0	0	10	2	0	0	0	0	0	0	7	4
D404	0	0	0	0	0	0	0	0	0	0	10	0	0	0	4	0	0	0
D405	6	5	5	0	0	0	0	0	10	0	0	0	0	0	0	0	5	5
D406	10	10	10	0	6	0	0	0	10	0	0	0	0	0	0	0	5	5
D407	10	10	10	0	6	0	0	0	10	0	0	0	0	0	0	0	5	5
D408	10	10	10	0	6	0	0	0	10	0	0	0	0	0	0	0	5	2
D409	10	10	10	0	6	0	0	0	10	0	0	0	0	0	0	0	5	4
D410	10	10	10	0	6	0	0	0	10	0	0	0	0	0	0	0	8	2
D411	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0
D412	10	10	10	0	0	0	0	0	10	0	0	0	0	0	0	0	10	10
D413	10	10	10	6	6	0	0	8	8	0	0	4	4	0	0	0	10	10
D414	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D415	0	0	0	0	0	0	0	0	0	0	10	8	8	0	4	0	0	0
D416	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D417	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0
Sub-total	106	105	105	34	61	0	0	27	107	6	25	36	16	4	10	0	73	57
Total	382	333	335	163	202	6	19	174	308	45	40	72	54	52	14	80	241	194

TABLE V (con.)

RELATIVE IMPORTANCE OF DATA REQUIREMENTS (R_i) IN DECISION CRITERIA (D_j)

	R 301	R 302	R 303	R 304	R 305	R 306	R 307	R 308	R 309	R 310	R 311	R 312	R 313	R 314	R 315
D101	8	8	2	2	5	2	0	2	2	5	0	0	0	0	0
D102	8	8	2	2	5	2	0	2	2	5	0	0	0	0	0
D103	6	6	0	0	0	0	0	0	0	0	0	0	0	0	0
D104	6	6	0	0	0	0	0	0	0	0	0	0	0	0	0
D105	10	10	8	6	4	3	9	6	4	4	0	8	9	6	0
D106	10	6	6	2	0	0	0	0	0	0	0	8	8	0	0
D107	10	8	2	1	0	0	0	0	0	0	0	0	0	0	0
D108	10	0	0	6	0	0	8	5	0	0	9	9	8	0	0
D109	10	0	5	5	0	0	0	0	0	0	10	9	9	0	0
D110	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0
Sub-total	88	62	25	24	14	7	17	15	8	14	19	34	34	6	0
D201	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D202	10	10	6	6	7	4	0	4	4	4	0	0	0	0	0
D203	10	9	6	6	7	4	0	4	4	4	0	0	0	0	0
D204	10	9	6	6	6	4	0	4	4	4	0	0	0	0	0
D205	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D206	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0
D207	10	10	4	4	4	4	0	4	4	4	0	0	0	0	0
D208	10	10	4	4	4	4	0	4	4	4	0	0	0	0	0
D209	8	6	0	0	0	0	0	0	0	0	0	0	0	0	0
D210	10	8	0	0	0	0	0	0	0	0	0	0	0	0	0
D211	10	10	10	8	0	0	0	0	0	0	10	8	8	0	0
D212	10	8	10	0	0	0	0	0	0	0	10	6	8	0	0
D213	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D214	10	8	8	7	4	0	0	4	4	4	0	0	0	0	0
D215	10	8	8	7	4	0	0	4	4	4	0	0	0	0	5
D216	10	8	0	0	0	0	0	0	0	0	0	0	0	0	0
Sub-total	128	114	62	48	36	20	0	28	28	28	20	14	16	0	5

TABLE VI

RELATIVE IMPORTANCE OF DATA REQUIREMENTS (R_i) IN DECISION CRITERIA (D_j)

	R 301	R 302	R 303	R 304	R 305	R 306	R 307	R 308	R 309	R 310	R 311	R 312	R 313	R 314	R 315
D301	10	9	8	4	4	4	0	4	4	4	0	0	0	0	0
D302	8	8	0	0	0	0	0	0	0	0	0	0	0	0	0
D303	8	8	0	0	0	0	0	0	0	0	0	0	0	0	0
D304	10	9	0	4	4	4	0	4	4	4	0	0	0	0	0
D305	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D306	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0
D307	10	8	0	0	0	0	0	0	0	0	0	0	0	0	0
D308	0	8	10	9	9	0	9	8	0	0	0	8	0	0	0
D309	6	8	10	9	9	0	9	8	0	0	0	8	0	0	0
D310	6	8	10	9	9	0	9	8	0	0	0	8	9	0	0
D311	9	9	0	8	0	0	4	4	0	0	0	0	0	0	0
D312	0	0	0	0	0	0	0	8	0	0	10	6	0	0	0
D313	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D314	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sub-total	70	77	38	43	35	8	31	36	8	8	10	30	9	0	0
D401	10	8	8	4	4	4	0	4	4	0	0	0	0	0	0
D402	10	8	0	0	0	0	0	0	0	0	0	0	0	0	0
D403	10	8	6	0	0	0	0	0	0	0	0	0	0	0	0
D404	10	6	0	0	0	0	0	0	0	0	0	0	0	8	0
D405	10	6	0	0	0	0	0	0	0	0	0	0	0	0	0
D406	10	9	0	0	0	0	0	0	0	0	0	0	0	0	0
D407	10	9	10	5	5	4	0	4	4	4	0	0	0	0	0
D408	10	9	0	0	0	0	0	0	0	0	0	0	0	0	0
D409	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0
D410	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0
D411	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0
D412	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D413	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0
D414	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D415	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0
D416	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D417	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sub-total	120	103	24	9	9	8	0	8	8	4	0	0	0	14	0
Total	406	356	149	124	94	43	48	87	52	54	49	78	59	20	5

TABLE VI (con.)

IMPORTANCE = (No. of entries)(Wt factor)(scale factor of 0.01)
= $(n)(w_i)(0.01)$

IMPORTANCE OF OCEANOGRAPHIC DATA REQUIREMENTS

1 thru 48 top priority

Data Requirements	Number of Entries	Weighting Factor	Importance	Ranking by Importance → 1 thru 48
2 mean R - 101 WAVE HEIGHT	46	386	177.5	47
102	38	242	91.9	40
103	36	193	69.4	38
104	31	137	42.4	36
105	23	142	32.6	31
106	11	54	5.9	18
107 *	39	318	12.4	27
108 *	34	207	7.0	21
109 *	30	158	4.7	15
110 *	22	84	1.8	5
111 *	25	133	3.2	12
112	24	169	40.5	33
113	6	44	2.6	9
114	17	40	6.8	19
115	6	52	3.0	11
3 SOUND R - 201 VELOCITY	41	382	156.6	46
6 RMS HORIZ S.V. FLUCTUATION AND 202 CORRELATION DIST. VS. DEPTH	40	333	133.0	43
5 MEAN HORIZ. S.V. GRAD. VS. DEPTH 203	40	335	134.0	44
204	26	163	42.3	35
205	30	202	60.6	37
206	1	6	0.1	2
207	12	19	2.2	7
208	24	174	41.7	34
7 SPECTRAL, INTEN. AND DIRECTIONAL 209 DISTRIBUTION OF AMBIENT NOISE	36	308	110.8	42
~~[illegible]~~ INTEN. ~~[illegible]~~ 210 ~~[illegible]~~ N OF ~~[illegible]~~ NOISE	17	45	7.6	23
211	5	40	2.0	6
212	12	72	8.6	25
213	9	54	4.8	16
214	7	52	3.6	13
215	4	14	0.5	3
216	11	80	8.8	26
217	40	241	96.4	41
218	39	194	75.6	39
1 → OCEAN R - 301 DEPTH	44	406	178.6	48 ←
4 BOTTOM ELEVATION 302 SLOPE SPECTRA	43	356	153.0	45
303	22	149	32.7	32
304	23	124	28.5	30
305	17	94	15.9	28
306	12	43	5.1	17
307	6	48	2.8	10
308	19	87	16.5	29
309	14	52	7.2	22
310	13	54	7.0	20
311	5	49	2.4	8
312	10	78	7.8	24
313	7	59	4.1	14
314	3	20	0.6	4
315	1	5	0.1	1

*Arctic Data Requirements were reduced further by a scaling factor of 0.1

TABLE VII

TABL

IMPORTANCE OF OCEANOGRAPHIC SUBDIVISIONS AND F

	WEIGHTING FACTORS	UNDERWATER ACOUSTICS	OCEANOGRAPHIC FORECASTING	SEA FLOOR	TURBULENCE	SURFACE AND INTERNAL WAVES	OCEAN SU BOTT
ANTISUBMARINE OPERATIONS	(5)	10	8	10	6	7	8	1
SUBMARINE OPERATIONS	(5)	10	4	10	6	6	8	1
AMPHIBIOUS OPERATIONS	(5)	7	10	6	2	6	4	
STRIKING FORCE OPERATIONS	(5)	6	10	6	2	7	4	
LOGISTIC SUPPORT OPERATIONS	(5)	6	8	6	2	6	4	
MINING AND MINE COUNTER-MEASURE OPERATIONS	(5)	8	4	10	5	8	4	
ARCTIC OPERATIONS	(3)	4.2	6.0	4.2	1.2	2.4	0.6	
SEARCH AND RESCUE OPERATIONS	(2)	2.0	1.6	3.2	0.4	2.8	0.4	
NAVAL DEVELOPMENT	(5)	10	4	8	7	8	6	
TOTAL IMPORTANCE VALUES*		63.2	55.6	63.4	31.6	53.2	39.0	5
RANKING BY IMPORTANCE*		17	16	18	6	14	11	1

*High values indicate high importance and high rank of importance

!

top priority

TABLE VIII

ONS AND FUNCTIONS IN NAVAL OPERATIONS AND DEVELOPMENT

SURFACE AND INTERNAL WAVES	OCEAN SUB-BOTTOM	SOUND VELOCITY	ELECTROMAGNETICS	CURRENTS	MARINE BIOLOGY	GEODESY, MAGNETICS, AND GRAVITY	OCEANOGRAPHIC ENGINEERING	LITTORAL	NUCLEAR EFFECTS	MARINE CHEMISTRY	DESCRIPTIVE OCEANOGRAPHY	SEA ICE	TIDES
	8	10	6	4	8	5	8	5	4	5	4	2	2
	8	10	8	5	6	6	6	5	4	3	6	2	1
	4	5	2	2	3	2	3	10	1	1	2	1	9
	4	5	1	2	3	4	1	1	1	1	1	2	1
	4	5	1	2	3	4	1	7	1	1	1	3	6
	4	6	4	5	4	9	5	10	1	5	4	3	3
.4	0.6	4.2	4.2	1.8	1.2	1.2	1.8	1.8	1.2	1.2	3	6	1.2
.8	0.4	2.4	1.2	3.2	3.6	0.4	3.2	0.4	1.6	0.4	2.4	0.4	0.4
	6	7	7	8	8	6	6	4	7	7	3	4	3
.2	39.0	54.6	34.4	33.0	39.8	37.6	35.0	44.2	21.8	24.6	26.4	23.4	26.6
[illegible]	11	15	8	7	12	10	9	13	1	3	4	2	5

2

TABLE IX

GUIDE FOR OCEANOGRAPHIC PRO

Class	Ranking by Importance	Relative Status of Knowledge 1-10	Priority	Necessary Research Prog
Sea Floor	18 Top	4	16	1. Definition of morphologi provinces of sea floor ar characteristics of each. 2. Model for sediment tran including dune movemen
Underwater Acoustics	17	3	18 Top priority	1. Models for boundary ref energy loss, scattering, signal distortion; cohere ambient noise; and multi propagation.

TABLE IX

GUIDE FOR OCEANOGRAPHIC PROGRAM PLANNING

'riority	Necessary Research Programs	Necessary Development and Survey Programs
16	1. Definition of morphological provinces of sea floor and characteristics of each. 2. Model for sediment transport including dune movement.	1. Accurate bathymetric charts of sea floor. 2. Establish slope and elevation spectra and physical, acoustical, electrical, and engineering properties of sediments. 3. Relate 2 above to sound reflection, scattering, phase distortion, and bearing accuracy. 4. Establish probability of mine penetration and burial and relate to degradation in performance. 5. Relate mine spacing doctrine and probability of case-anchor separation to sea floor characteristics.
Top priority 18	1. Models for boundary reflection, energy loss, scattering, and signal distortion; coherence; ambient noise; and multipath propagation.	1. Identification and determination of relative importance and directional characteristics of all sources of ambient noise. 2. Measurement of coherence and distortion of underwater sound signals -- statistical description of signals. 3. Relate bottom reflection loss, scattering, phase distortion, and bearing accuracy to sea floor elevation, slope spectra and bottom and subbottom properties. 4. Measure absorption of sound in sea ice, marine sediments, and underlying strata. 5. Verify model relating surface noise to sea surface waves.

2

TABLE

Class	Ranking by Importance	Relative Status of Knowledge 1-10	Priority	Necessary Rese
Oceano-graphic Forecasting	16	3	17	1. Model for air processes re propagation, tional proper waves. 2. Refinement o ers and surf 3. Improvement temperature 4. Establish tec casting ocean
Sound Velocity	15	5	12	1. Models of the variability of the sea; in se file of spatial sound velocit floor.
Surface and Internal Waves	14	4	14	1. Model for the propagation, internal wave 2. Refinement o surface wave 3. Model for sh 4. Establish sec tistics of sea

TABLE IX (con.)

ority	Necessary Research Programs	Necessary Development and Survey Programs
17	1. Model for air-sea boundary processes related to the growth, propagation, decay, and directional properties of surface waves. 2. Refinement of model for breakers and surf forecasting. 3. Improvement of model for sea temperature forecasting. 4. Establish techniques for forecasting ocean currents.	1. Verification of sea-ice forecasts. 2. Improve techniques for optimum ship routing. 3. Improve reliability of antisubmarine, submarine, amphibious, mining and mine countermeasure, and nuclear effects operational forecasts.
12	1. Models of the distribution and variability of sound velocity in the sea; in sea ice; and the profile of spatial variations of sound velocity within the sea floor.	1. Verification of models. 2. Direct measurements of sound velocity, particularly adjacent to sea floor.
14	1. Model for the generation, propagation, and decay of internal waves (all modes). 2. Refinement of model for the surface wave spectrum (SWS). 3. Model for shallow water SWS. 4. Establish second order statistics of sea surface.	1. Verify relationship of surface elevation, slope, and curvature spectra to SWS. 2. Establish hull design criteria from SWS. 3. Relate surface sound reflection and reverberation to SWS. 4. Relate radar clutter to SWS. 5. Relate bottom pressure fluctuations to SWS in shallow water. 6. Relate internal wave structure to sound propagation fluctuations.

2

TABLE IX (con.)

Class	Ranking by Importance	Relative Status of Knowledge 1-10	Priority	Necessary Research Pro
Littoral	13	7	6	1. Model for longshore an currents. 2. Model for sediment tr including dune movem
Marine Biology	12	5	9	1. Establish patterns of c tration and movement marine life. 2. Model of marine foulin depths. 3. Determine acoustical s ing and reflective char istics of biological pop (phytoplankton, zooplar nekton).
Ocean Subbottom	11	3	13	1. Definition of nature of subbottom

TABLE IX (con.)

rity	Necessary Research Programs	Necessary Development and Survey Programs
6	1. Model for longshore and rip currents. 2. Model for sediment transport including dune movement.	1. Identification and warning of wrecks, modifications in status of navigational aids, and hazards to navigation and piloting. (operational) 2. Specification of beach trafficability in amphibious objective areas. 3. Charting of underwater hazards (natural and man-made) restrictive to amphibious landings.
	1. Establish patterns of concentration and movement of marine life. 2. Model of marine fouling at all depths. 3. Determine acoustical scattering and reflective characteristics of biological populations (phytoplankton, zooplankton, nekton).	1. Define probability of occurrence and movement of deep scattering layer. 2. Establish probability of false (biological) sonar contacts - time and space. 3. Relate marine fouling (boring) to degradation of mine and acoustical system performance and life expectancy. 4. Establish biological effect on characteristics of sea surface. 5. Techniques for survival at sea.
	1. Definition of nature of ocean subbottom	1. Delineation of strata within unconsolidated sediments and between other subbottom layers. 2. Determine depth, roughness of boundaries, and physical - acoustical properties of subbottom strata.

TABLE IX (con.)

Class	Ranking by Importance	Relative Status of Knowledge 1-10	Priority	Necessary Research Programs	
Geodesy, Magnetics, and Gravity	10	5	8	1. Model of earth's gravimetric and magnetic fields.	1. 2. 3.
Oceano-graphic Engineering	9	5	7	1. Investigate high-pressure effects on materials. 2. Discovery of corrosion resistant alloys. 3. Investigate wave effects on structures.	1.
Electro-magnetics	8	4	11	1. Model of infrared emissivity of sea surface. 2. Model of reflectivity of electromagnetic energy from sea surface. 3. Relate light extinction coef-ficient to other properties. 4. Model for electromagnetic propagation in sea floor.	1. 2. 3.

TABLE IX (con.)

ssary Research Programs	Necessary Development and Survey Programs
del of earth's gravimetric l magnetic fields.	1. Delineation of areas of high geomagnetic field strength gradients. 2. Measurement of magnetic field intensity fluctuations applicable to mine design. 3. Measurement of magnetic field adjacent to sea floor.
estigate high-pressure ects on materials. scovery of corrosion sistant alloys. estigate wave effects on uctures.	1. Development of improved oceanographic instruments, sensors, buoys, offshore towers, and underwater vehicles
del of infrared emissivity sea surface. del of reflectivity of ctromagnetic energy from surface. late light extinction coef- ent to other properties. del for electromagnetic pagation in sea floor.	1. Measurement of light transmission or extinction coefficients. 2. Verify radio wave attenuation in sea water. 3. Measure electromagnetic noise in the sea.

TABLE IX (con.)

Class	Ranking by Importance	Relative Status of Knowledge 1-10	Priority	Necessary Research Progr
Currents	7	4	10	1. Models for circulation, w driven, tidal, inertial, ro and wave currents, incluc subsurface and abyssal cu 2. Definition of current boun and theory of movement.
Turbulence	6	2	15	1. Define nature of turbulenc the sea. 2. Statistical model of therm patches. 3. Model of convergence and divergence zones and theo of movement of oceanogra fronts.
Tides	5	8	1	1. Refinement of tidal predic for continental harbors, s lines, coastal areas, and islands. 2. Model for prediction of st surges. 3. Model for prediction of ts nami propagation and effe

TABLE IX (con.)

Necessary Research Programs	Necessary Development and Survey Programs
1. Models for circulation, wind-driven, tidal, inertial, rotary, and wave currents, including subsurface and abyssal currents. 2. Definition of current boundaries and theory of movement.	1. Verification of models. 2. Investigate sound propagation through current boundaries, regions of convergence and divergence, and oceanographic fronts. 3. Establish effect of currents on sonobuoy performance.
1. Define nature of turbulence in the sea. 2. Statistical model of thermal patches. 3. Model of convergence and divergence zones and theory of movement of oceanographic fronts.	1. Measure and characterize thermal microstructure at all depths. 2. Relate thermal microstructure to apparent sound transmission errors and intensity fluctuations.
1. Refinement of tidal predictions for continental harbors, shorelines, coastal areas, and islands. 2. Model for prediction of storm surges. 3. Model for prediction of tsunami propagation and effect.	1. Verification of models. 2. Effect of tides on shallow-water sound propagation.

TABLE IX (con.)

Class	Ranking by Importance	Relative Status of Knowledge 1-10	Priority	Necessary Research Programs
Descriptive Oceanography	4	6	3	1. Delineate water mass boundaries
Marine Chemistry	3	5	4	1. Model for predicting rates of corrosion of metals and alloys. 2. Investigation of gases, dissolved and undissolved. 3. Isotopic composition of sea water.
Sea Ice	2	6	2	1. Nature of the formation, growth, drift, transitional states, and melting of sea ice. 2. Model for the prediction of sea ice coverage and thickness at specified time and location.
Nuclear Effects	1	4	5	1. Model of turbulent diffusion and advection of radioactive products from point source at various depths. 2. Model for shock wave propagation. 3. Identification of radioactive isotopes and natural levels in the sea.

TABLE IX (con.)

ry Research Programs	Necessary Development and Survey Programs
eate water mass boundaries.	1. Definition of mean temperature, salinity, and density fields and a statistic of variability.
l for predicting rates of sion of metals and alloys. tigation of gases, dis- d and undissolved. pic composition of sea .	1. Establish relationship of dissolved salts to sound absorption at frequencies less than 1000 cycles. 2. More detailed determination of constituents of sea water. 3. Relate near-surface bubble concentration to acoustical absorption, scattering, and reflection.
re of the formation, growth, transitional states, and ng of sea ice. l for the prediction of sea overage and thickness at fied time and location.	1. Determine characteristic depression and slope spectra of sea ice. 2. Determine physical, acoustical, and electromagnetic properties of sea ice and changes throughout period of a year. 3. Model for the formation and distribution of ice pressure ridges. 4. Relate sea ice properties to propagation and reverberation of sound in Arctic.
l of turbulent diffusion and ction of radioactive pro- from point source at us depths. l for shock wave propaga- ification of radioactive pes and natural levels in ea.	1. Verification of models. 2. Investigate harbor and estuarine circulation. 3. Establish safe and lethal firing distances for nuclear devices.

TABLE X

COMPARISON OF RANKING BY IMPORTANCE IN TENOC WITH OCEANOGRAPHIC DATA REQUIREMENTS

TENOC	RANK	DATA REQUIREMENTS		RANK
Sea Floor	18	R301	Ocean Depth	48
		R302	Bottom elevation and slope spectra	45
		R303	Surface sediment density and porosity	32
		R304	Thickness of sedimentary layer	30
		R308	Ratio of sediment to exposed pebbles, rock, or nodules on sea floor	29
		R312	Probability of turbidity currents	24
		R307	Surface sediment grain size and shear strength	10
		R314	Color of bottom sediments	4
Underwater Acoustics	17	R209	Spectral intensity and directional distribution of ambient noise	42
		R217	Sound absorption	41
		R218	Boundary scattering, reflectivity, and absorption	39

TABLE X (Con.)

COMPARISON OF RANKING BY IMPORTANCE IN TENOC WITH OCEANOGRAPHIC DATA REQUIREMENTS

TENOC	RANK	DATA REQUIREMENTS		RANK
Oceanographic Forecasting	16	All comparable data requirements		
Sound Velocity	15	R201	Sound velocity, continuous profile to bottom	46
		R203	Mean horizontal sound velocity gradient vs depth	44
		R202	RMS horizontal sound velocity fluctuation and correlation distance vs depth	43
		R303	Sound velocity and sound absorption of sediment	32
		R310	Sound velocity of sub-sediment layers	20
		R311	Sound velocity and sound absorption of sea ice	12
Surface and Internal Waves	14	R101	Mean wave height	47
		R202	Surface elevation, slope, and curvature spectra	40
		R103	Direction of primary surface waves	38
		R104	Second order statistics of sea surface	36

TABLE X (Con.)

COMPARISON OF RANKING BY IMPORTANCE IN TENOC
WITH OCEANOGRAPHIC DATA REQUIREMENTS

TENOC	RANK	DATA REQUIREMENTS		RANK
Surface and Internal Waves (con.)	14	R311	Bottom pressure spectra	8
		R210	Internal wave elevation spectrum vs depth	23
Littoral	13	All comparable data requirements		
Marine Biology	12	R205	Probability of occurrence depth, and scattering strength of biological scattering layer(s)	37
		R208	False target density	34
		R216	Rate of accretion of marine growth on various surfaces	26
		R215	Probability of bioluminescence	3
Ocean Subbottom	11	R310	Density and rigidity of sub-sediment layers	20
		R309	Depth, thickness, and boundary roughness of sub-sediment layers	22
		R305	Density and rigidity of intrasediment layers	28

TABLE X (Con.)

COMPARISON OF RANKING BY IMPORTANCE IN TENOC WITH OCEANOGRAPHIC DATA REQUIREMENTS

TENOC	RANK	DATA REQUIREMENTS		RANK
Ocean Subbottom (con.)	11	R306	Depth of boundaries and thickness of intrasediment layers	17
Geodesy, Magnetics, and Gravity	10	R213	Geomagnetic field strength, field strength gradients, and fluctuations	16
		R315	Gravimetric profiles	1
Oceanographic Engineering	9	All comparable data requirements		
Electromagnetics	8	R212	Spectral intensity and directional distribution of electromagnetic noise	25
Currents	7	R204	Ocean current speed and direction profile to bottom	35
		R105	Surface current	31
		R106	Differential surface current for various separation distances	18
Turbulence	6	R204	Ocean current speed and direction profile to bottom	35

TABLE X (Con.)

COMPARISON OF RANKING BY IMPORTANCE IN TENOC WITH OCEANOGRAPHIC DATA REQUIREMENTS

TENOC	RANK	DATA REQUIREMENTS		RANK
Turbulence (con.)	6	R112	Water temperature	33
		R114	Salinity	19
Tides	5	R214	Tidal range and level	13
Descriptive Oceanography	4	R112	Water temperature	33
		R114	Salinity	19
		R113	Air-sea temperature difference	9
		R313	Water temperature	14
		R115	Frequency of fog and precipitation	11
Marine Chemistry	3	R206	Dissolved Oxygen concentration	2
		R207	Probability of presence and concentration of entrapped or undissolved gas	7
Sea Ice	2	R107	Areal coverage and limit of sea ice	27
		R108	Thickness of sea ice	21

TABLE X (Con.)

COMPARISON OF RANKING BY IMPORTANCE IN TENOC
WITH OCEANOGRAPHIC DATA REQUIREMENTS

TENOC	RANK	DATA REQUIREMENTS		RANK
Sea Ice (Con.)	2	R109	Maximum depth of ice islands, pressure ridge projections, and icebergs	15
		R110	Sea ice depression and slope spectra	5
Nuclear Effects	1	R204	Ocean current, speed and direction profile to bottom	35
		R112	Water temperature	33
		R114	Salinity	19
		R201	Sound velocity, continuous profile to bottom	46

APPENDIX A. LIST OF ENVIRONMENTAL EFFECTS

HIGH SURFACE WAVES

1. Reduce ship maneuverability and stability (increase pitch, yaw, heave, sway, roll and surge)

2. Reduce ship speed

3. Contribute to ship icing

4. Degrade effectiveness of search and rescue operations

5. Induce quenching

6. Reduce magnetic anomaly detection equipment detection probability

7. Reduce probability of detecting snorkles and periscope with radar

8. Prevent or hamper seaplane landing and takeoff

9. Render carrier aircraft landing more difficult

10. Prevent or hamper underway refueling operations

11. Decrease probability of infrared detection

12. Interfere with recovery of ordnance units

13. Affect firing of underwater-to-air missiles

14. Interfere with hydrofoil operation

15. Decrease ship loadline limits

16. Damage or destroy beach facilities and installations

17. Damage or destroy buoys, towers, net, etc.

18. Produce high ambient noise

19. Induce microbubbles

20. Produce subsurface and surface currents

21. Affect near-surface sound velocity structure

22. Increase acoustic loss by scattering at the sea surface

23. Reduce ship's personnel effectiveness

24. Reduce visual detection of surface objects

25. Affect fire control

26. Affect cable-laying capability

27. Produce serrated bottom profiles in hydrographic survey operations

28. Prevent or hamper the launch or recovery of small boats

29. Prevent or hamper underway resupply operations

30. Reduce sensitivity of instrumentation, such as magnetic compass and gyrocompass

31. Deterrence to minelaying and minehunting operations

32. Adversely affect gyro stablization for navigational and tracking devices

33. Adversely affect ship's true heading and constant speed for navigational dead reckoning

34. Degrade inertial navigational systems

35. Degrade all celestial observation navigational systems

36. Degrade operational effectiveness of doppler shift navigational systems

37. Degrade operational effectiveness of directional UHF and VHF ranging systems

38. Degrade operational effectiveness of bathymetric navigational system

39. Produce severe stress on large shipboard antenna systems

40. Cause loss of drag wire antenna and buoy systems

41. Affect radar target detection

INTERNAL WAVES

1. Cause time changes in water density which affect buoyancy

2. Produce variations in acoustic signal intensity and sound velocity structure in general

3. Affect transmission of shock wave

UNDERWATER SOUND VELOCITY STRUCTURE

1. Influences sonar range, range variations, and bearing

2. Increases or decreases sonar probability of detection at various target ranges

3. Determines acoustic propagation path (i.e., type of sonar for use in a particular area)

4. Affects ability to determine true water depth by acoustic means

5. Influences choice of mode of sonar operation (surface duct, convergence zone, or bottom bounce)

6. Influences coherence of acoustic signal

7. Influences accuracy of navigational fixes obtained with sonar beacons

8. Influences missile impact locations utilizing sound channel axis velocities

9. Influences selection of VDS towing depth

10. Affects transmission of shock waves

SEICHES, TSUNAMIS, TIDES

1. Affect water temperature and sound velocity structure

2. Destroy and/or damage shore and harbor facilities

3. Cause variations in water depth

4. Affect current speed and direction

5. Alter sea surface slope

6. Affect movement, burial, and effectiveness of bottom mines

TURBULENCE

1. Affects dispersion of contaminants

2. Appears as noise to hydrophones mounted on fast moving objects

3. Interferes with infrared detection

4. Interferes with visual detection (particularly in shoal waters)

5. Affects short-period fluctuations in sound velocity

6. Induces high background noise which affects performance of passive listening devices

7. Increases absorption and scattering of underwater sound

BOTTOM SEDIMENTS

1. Affect acoustic bottom loss

2. Affect reverberation, acoustic scattering, and reflectivity

3. Characterize mechanical properties of the bottom (i.e., bearing strength, abrasive qualities, anchor holding qualities, and roughness)

4. Influence bottom stability

5. Influence faunal growth

BATHYMETRY

1. True depth required to determine bottom-bounce sonar range

2. True depth required to determine probability of convergence zone propagation

3. Bottom slope required to determine bottom-bounce sonar bearing error

4. Bottom slope required to determine bottom loss of acoustic energy

5. Bottom topography used in bathymetric navigation

6. Bottom roughness affects bottom loss of acoustic energy and reverberation

7. Available depth, especially in shallow areas and under ice, will determine submarine transiting routes

8. Deep submersibles can use topography as a shield from passive or active acoustic arrays

9. Variations in depth cause gravity anomalies which affect inertial navigation

10. Pinnacles, wrecks, etc. may appear as false targets to sonar

11. Is a basic consideration in site location for bottom-mounted hydrophone and transducer arrays

12. Is essential in laying undersea cable and implantment of structures on or near the sea floor

MAGNETIC STORMS

1. Affect long-range radio transmission

2. Affect electronic navigation equipment

3. Affect magnetic compass

4. Prevent localization search by Magnetic Anomaly Detection (MAD) systems

5. Affect magnetic influence mechanisms

MAGNETIC FIELD

1. Magnetic field charts can be used as a passive navigation system

2. Useful in geologic interpretation

3. Determines variation of magnetic compass

4. Strong bottom anomalies appear as targets on MAD equipment

GRAVITY FIELD

1. Useful in passive navigation

2. Affects inertial navigation

3. Affects satellite in-flight motions

4. Affects FBM launch and flight

5. Complements seismic and magnetic measurements in geologic interpretation

6. Affects determination of local geodetic datum

BIOLOGICAL FOULING

1. Increases drag on ships, cables, buoys, etc.

2. Alters performance characteristics of hydrophones

3. Information required to devise anti-fouling techniques

4. Changes color of submerged objects or submarines

5. Borers affect underwater cables and structures

BIOLUMINESCENCE

1. Enhances visual detection of wakes

2. Silhouettes submarines, buoys, nets, etc.

FISH, MAMMALS, ETC.

1. False sonar targets

2. Dangerous to man

3. Produce ambient noise

PLANKTON, FISH SCHOOLS, FLOATING ALGAE, SEAWEED, DEEP SCATTERING LAYERS

1. Contribute to sound attenuation, scattering, and volume reverberation

2. Increase gas content of water

3. Decrease water clarity

4. Clog water intakes, evaporators, coolers, etc.

5. Seaweed affects small boat and hydrofoil operations

6. False sonar targets

7. Produce ambient noise

8. Kelp provides hiding places for submarines

ICE

1. Prohibits or hinders surface navigation

2. Hinders subsurface navigation (underwater ice projections)

3. Affects submarine ability to surface

4. Forces submarine below radio reception depth

5. Attenuates radio signals

6. Moves or destroys nets, buoys, etc.

7. Degrades sound propagation above frequencies of 100 cps

8. Prohibits submerged transit of shallow areas

9. Affects ambient noise level

10. Prohibits or hinders delivery of weapons

11. Appears as false targets

12. Produces acoustic, visual, or radar shadow zones

AMBIENT NOISE

1. Biological, surface wave, ice, or shipping noises degrade acoustic detection system performance

2. Provides cover for hiding submarines

OPTICAL PROPERTIES

1. Light transmission coefficients will become more important if an operational laser is developed

2. Water clarity affects use of underwater television, photographic cameras, etc.

3. Water clarity affects visual sighting of underwater objects

4. Water clarity affects SCUBA divers effectiveness

MICROBUBBLES AND GAS CONTENT

1. Gas content affects sonar dome cavitation

2. Oxygen content affects corrosion rates

3. Microbubbles attenuate acoustic and light energy

4. Affects propeller cavitation and deterioration

TEMPERATURE

1. Influences sound velocity structure

2. Influences distribution of marine life

3. Influences density of sea water (buoyancy and currents)

4. Influences conductivity of sea water

5. Affects ship power plant efficiency

6. Affects radio signal propagation

SALINITY

1. Influences sound velocity structure

2. Affects corrosion

3. Influences density of sea water

4. Influences conductivity of sea water

DENSITY

1. Influences sound velocity structure

2. Affects ship loadline limits

3. Influences buoyancy of submarines

4. Influences vertical motion of sea water

CONDUCTIVITY

1. Affect electrical and magnetic propagation

CURRENTS

1. Set and drift affect accurate navigation (surface and subsurface)

2. Adversely affect performance of inertial navigation systems

3. Currents aid or hinder submarines attempting quiet, slow-speed transits through strait areas

4. Affect search and rescue operations

5. Affect recovery of ordnance units

6. Place additional drag on moors, nets, buoys, etc.

7. Affect cable and mine laying operations

8. Give apparent motion to bottom features such as pinnacles and other false targets

9. Scour around bottomed objects

10. Produce ambient noise on bottom hydrophones

11. Affect flushing and dispersion of contaminants

12. Affect diver operations

13. Affect earth's electric field and therefore magnetic field

14. Affect distribution of oceanographic and meteorological environmental parameters

RADIOACTIVITY

1. Level of natural or induced radioactivity affects radioactive sensors

SLICKS

1. Show high readings on wake detectors

2. Indicate fluctuations in acoustic transmission